period of growth the apex of this organ became more or less spherical, and finally withered away.

Similar results had been obtained with the haustoria (modified roots) of Cuscuta, in a former research of George Peirce's.

Another interesting achievement of the same worker was to grow specimens of Pisum as parasites upon other plants, from the seedling stage until flowering. The host which gave the most favourable results appears to have been *Impatiens sultani*.

The young Pisum grown under these unwonted conditions produced an almost normal root system, with numerous side branches; but the stem was stunted in its growth, although it bore leaves and a few flowers. The roots, it may be mentioned, were here also devoid of hairs. This experiment is extremely interesting in a great many ways. It shows, in the first place, how fine is the line of demarcation between an ordinary earth-grown plant, such as Pisum, and a phanerogamous parasite, especially a partial parasite like mistletoe.

Again, it has a physiological interest; it is suggestive of a new path of research. A strict and careful comparison of the details of outward form and internal anatomy in a normally grown Pisum, or other plant, with those found in one which is, so to speak, an induced parasite, must, beyond all doubt, shed much light upon the relationship between the shape and structure of an organism and its surroundings.

We know but too little of this branch of biology at present.

Why an organ should be shaped this way in one individual and that way in another, may indeed be partially answered in some cases; but these instances are few, and the answers are incomplete, to say the least of them. RUDOLF BEER.

DR. A. SCHMIDT'S THEORY OF EARTHQUAKE-MOTION.

[NOTE.—The following pages contain a summary of an interesting but little known paper by Dr. August Schmidt, of Stuttgart. An English translation was prepared by the late Dr. E. von Rebeur-Paschwitz for the *Seismological Journal of Japan*, but arrived too late for publication in the concluding volume of the series. The original being too long for insertion in NATURE, I have condensed it at the translator's request, at the same time adhering as closely as possible to the author's words. The title of the paper is "Wellenbewegung und Erdbeben ein Beitrag zur Dynamik der Erdbeben" (*Jahreshefte des Vereins für vaterl. Naturkunde in Württemburg*, 1888, pp. 248-270). In a later paper (same journal, 1890, pp. 200-232), Dr. Schmidt applies his theory to the Swiss earthquake of January 7, 1889, and the Charleston earthquake of August 31, 1886.—C. DAVISON.]

SEISMOLOGISTS assume the propagation of earthquake-waves to take place uniformly in all directions; they regard the coseismal or wave-surfaces as concentric spheres, the rays as straight lines normal to the spheres. This, however, is an entirely unjustified assumption, which certainly facilitates the calculations, but leads to very doubtful results in determinations of the velocity of propagation and of the depth of the earthquake-centre. It is impossible that seismic rays should be straight lines, because the conditions on which the velocity depends undergo change with increasing depth below the surface. Though experimental determinations of the velocity do not agree with the theoretical value $\sqrt{e/d}$, yet it is clear that the velocity must depend on the density and elasticity of the rocks through which the wave is propagated. Now, the modulus of elasticity, owing to increased pressure, must increase with the depth below the surface; and therefore the velocity of the earthquake-wave must also increase with the depth.

As the velocity of propagation increases, the energy of a vibrating particle diminishes; and thus, as is well known to be the case, earthquakes should be less noticeable in mines than on the surface of the earth.

Amendment of Hopkins' Law.—Let us imagine a wave emanating from a deep centre and propagated in all directions. A vertical plane through the centre cuts all the successive coseismal surfaces, as well as the earth's surface. Let us suppose the section of the latter to be a horizontal straight line. The lower parts of Figs. 1 and 2 show the successive positions of the coseismal surfaces from minute to minute. Fig. 1, with its equidistant concentric coseismals and its straight rays, corresponds to the ordinary earthquake theory. Fig. 2, with its excentric coseismals approaching each other as they rise and with its curved rays convex downwards, represents our new theory. The horizontal straight line, dividing the upper part of the figures from the lower, represents the surface of the earth. In both figures, the rays at first appear equally distributed in all directions from the centre; in Fig. 1 they remain so, but in Fig. 2, in order to continue normal to the wave-surfaces, they must diverge at a much more rapid rate below than above, thus becoming convex downwards. Of course, Fig. 2 only represents a special law of increase of velocity with the depth—the velocity is supposed to vary as the depth—but the general character of the figure with its rays convex below remains the same if the law is a different one.

A comparison of the figures shows that in Fig. 2 there is a greater condensation of the seismic rays, and therefore a greater intensity of the shock, in the neighbourhood of the epicentre, and this corresponds better with the effects observed within the area of greatest disturbance.

But more important for our purpose are the sections of the earth's surface contained between two successive coseismals. Each of these sections is a measure of the distance through which the wave appears to progress from minute to minute at the surface. In reality it progresses obliquely from below in the direction of the rays, and the real distance through which it moves is smaller than the apparent one. We can only observe the apparent velocity at the surface. If we have at our disposal a sufficient number of good time-observations, we can draw the horizontal coseismal lines on a map and determine the apparent velocity from their relative distances. In both figures, the apparent velocity has its greatest value at the epicentre and decreases outwards. In Fig. 1, it gradually approaches asymptotically the true value in the direction of the rays. This is the law which Hopkins propounded in 1847. In Fig. 2, the apparent velocity at first diminishes rather rapidly, until it reaches the value of the true velocity at the depth of the centre, but afterwards it again increases gradually with the distance. We thus arrive at the following amendment of Hopkins' law, which will be expanded afterwards: the apparent velocity at the surface is never less than the true velocity at the centre, and varies with it.

Differences in Earthquake Velocities.—According to the old theory, every substance ought to possess its own velocity, dependent on its internal structure. The limit, which is defined by Hopkins' law as the lowest possible value of the apparent velocity, ought always to be the same in any given region. Experiments by Pfaff, Mallet, and Abbot lead to different values for different substances, as was to be expected. But they also show considerable variations in the same material, the velocity increasing with the strength of the initial impulse. Real earthquakes show even larger differences in velocity than artificial ones, and often earthquakes of less intensity are propagated with a greater velocity in the same region than very strong ones.

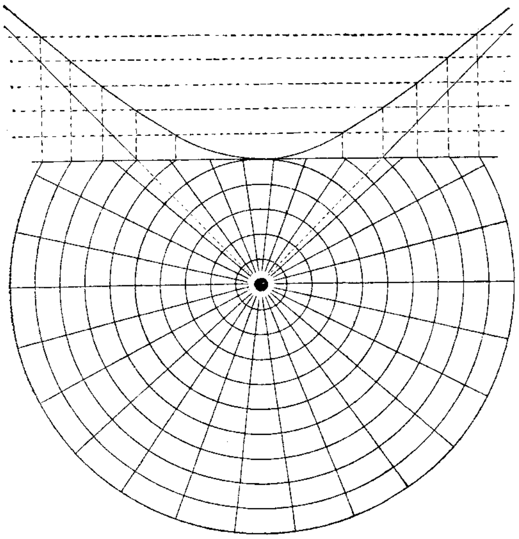
These differences are inconsistent with Hopkins' law. To be explained by the old theory, they require for the centres of earthquakes with great velocities an enormous depth below the surface, a near approach to the centre of the earth, for an earthquake emanating from the centre itself would arrive simultaneously at all points of the surface. With our new hypothesis, such differences are necessary, and even with the largest velocities the earthquake-centre may be at a considerable distance from the centre of the earth.

Proof of the Law.—The law that the velocity at the surface is never less than that at the earthquake-centre includes Hopkins' law. This indicates that the law is a general one. Its mathematical demonstration is contained in the law of refraction. We may distinguish the following three velocities: (1) the velocity at the centre, u_1; (2) the true velocity at the surface, *i.e.* that part of an earthquake-ray through which the wave progresses in one minute, u; (3) the apparent velocity at the surface, *i.e.* the horizontal distance between two successive coseismals corresponding to an interval of one minute, v. As an example, let us take in Fig. 2 the horizontal distance between the fourth and fifth coseismals from the epicentre as a representative of v, and let the section of the ray between the same coseismals near the surface represent u, and the distance between the centre and the first coseismal u_1. Then, if α be the angle between the ray and the vertical at the point where it meets the surface, we have $v = u/\sin\alpha$; and, if α_1 be the angle which the same ray makes with the vertical through the earthquake-centre, we have by the law of refraction $v = u/\sin\alpha = u_1/\sin\alpha_1$.

Now, let us consider the different rays emanating from the earthquake-centre. When α_1 is equal to zero, v is infinitely great. As α_1 increases, v decreases, until $\alpha_1 = 90°$. This corresponds to the ray which starts horizontally from the centre, and at the point where this ray reaches the surface we have $v = u_1$. When α_1 becomes obtuse, the value of sin α_1 decreases again, and v increases, though more slowly because the rays diverge more and more; but at an infinite distance v would again be infinitely great.

The only condition by which our law is bound is that the true velocity of the wave is always the same at the same depth; but the variation of velocity may follow any law. The law would even remain true if the velocity were to decrease with the depth; but in this case the rays would be concave downwards, and only a few would reach the surface. But, as we have every reason to believe that v increases with the depth, it follows that the rays must be convex downwards; and not only the ray which is horizontal at first bends upwards, but all rays do so in time. The whole disturbed area of an earthquake is thus divided into two zones: an inner circle in which the apparent velocity v decreases as the distance from the epicentre increases, and an outer ring in which v increases with the distance up to infinity. The inner circle is the region of the direct rays, the outer ring that of the earthquake energy which by refraction is brought up from below. The smallest value of v, corresponding to the boundary between the two zones, measures the velocity of propagation at the depth of the centre.

Fig 1

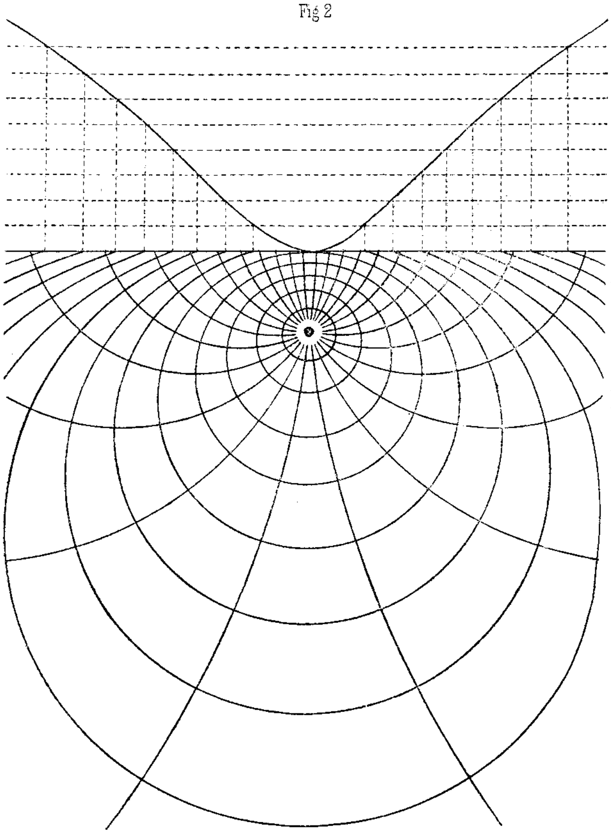


The effect of curvature of the earth's surface, which we have so far neglected, will consist in a diminution of the rate at which the velocity increases in the outer zone.

The Earthquake Hodograph.[1]—The law connecting the variations in the apparent velocity at the surface is best explained by the upper parts of Figs. 1 and 2. At the points where the surface line is cut by the coseismals, normals are erected to the surface of 1, 2, 3, &c., units in length, representing the differences in time from that at the epicentre. A curve passing through the ends of these normals represents what we call the hodograph. The greater the inclination of the curve to the surface line, the less is the apparent velocity, v, at the corresponding point of the curve. Where the curve is horizontal the velocity is infinitely great, where it is convex downwards the velocity decreases outwards, where it is concave the velocity increases. The hodograph in Fig. 1 is the hyperbola of von Seebach and Minnigerode. If we use the same scale for the units of time and velocity, the hyperbola is rectangular and the asymptotes are directed towards the centre. In Fig. 2, the hodograph is no longer hyberbolic; at the epicentre it is horizontal and convex downwards, gradually approaching a maximum inclination at a point of inflexion, after which it becomes concave downwards, and gradually becomes horizontal again at infinity. If, in the lower part of the figure, we follow the ray which leaves the centre horizontally until it reaches the surface, a normal erected at this point passes through the point of inflexion.

It is important to study the changes in the form of the hodograph as the depth of the centre gradually diminishes. The result is that the two points of inflexion move towards the epicentre, the convex portion becomes smaller, and so also does the "inner zone" of the disturbed area. When the centre and epicentre coincide, the convex portion of the curve and the inner zone of the disturbed area disappear entirely: the hodograph consists of two symmetrical concave branches which meet at an angle at the centre. This suggests to us how we should explain the results of measurements of velocities in artificial earthquakes. In a shock produced at the surface of the earth, the velocity must increase from the centre outwards. The stronger the charges of gunpowder are, the longer are the distances that can be employed in the experiments, and the greater the mean values of the velocity obtained.

Fig 2



Thus, the form of the hodograph will vary much with the depth of the centre, and it must also vary with the law which expresses the change of velocity with the depth. But, whatever be the unknown law, the hodograph must always be convex at the epicentre, and, passing through a point of inflexion, afterwards become slightly concave. This follows simply from the law of refraction without any regard to the rate at which the velocity increases with the depth.

As long as we do not possess a sufficiently large number of time-observations for at least one earthquake, it will be impossible to draw any conclusion concerning the law of velocity from the form of the hodograph. Even with the best observations, we can never, in drawing the hodograph, expect that all points will fall on a regular and continuous curve. But what we may expect is that, with a sufficiently large number of observations, the points will be distributed equally on both sides of such a curve. The hodograph contains the observations from places in all possible directions from the epicentre combined in a single plane. If the velocity is different in different directions, in the general figure these differences will be eliminated when the number of observations is large enough, and the result will be a curve free from local disturbances.

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[1] The name "hodograph" was given by Hamilton to a curve which represents graphically the variable velocity of a moving point. We do not think that any mistake can arise if we use this name for our purpose.

Although the time has not yet come for us to determine the definite form of an earthquake-hodograph, yet we know enough from the best examined earthquakes to decide whether the hodograph is an hyperbola or a curve with points of inflexion, whether Hopkins' law is confirmed by the observations, or an increase of velocity is noticeable in the outer zone of the disturbed area.

The best example for such an investigation is contained in von Seebach and Minnigerode's discussion of the earthquake of March 6, 1872, in Central Germany. An inspection of the map of coseismals published by them is sufficient to show that the horizontal coseismals are crowded together in a striking manner near Göttingen and Leipzig, at a distance of sixteen (German) miles from the epicentre. Accordingly, in drawing the hodograph we see how badly the hyperbola suits the observations. Several points which are most valuable for the determination of the epicentre, because they are nearest to it, and which agree most perfectly with one another, must be rejected in constructing the hyperbolic hodograph, in order that the earthquake may not begin at the surface of the earth until 1½ minutes after it was actually observed at five different places at five to six miles distance from the epicentre. For sixteen miles the hyperbola leaves all the best observations below it, after which nearly all points remain above it until it ends at Breslau, at a distance of fifty-seven miles from the epicentre. At this place a magnetic needle was found swinging by Prof. Galle at 4h. 5m. 25s., Berlin time, but the shock itself may have occurred several minutes earlier. The hyperbola is made to pass exactly through the point corresponding to this time, for otherwise its vertex would have to be placed still higher than it is now, and this would increase the already existing disagreement between the calculated time of the beginning of the earthquake and the actual observations.

How well, on the contrary, are the observations represented by a curve the vertex of which is a little below 3h. 55m., and, being convex downwards, passes at a distance of seven to eight miles between 3h. 55m. and 3h. 56m., reaches its points of inflexion at about eleven miles distance with a slope corresponding to 2·5 miles per minute, and then leaving some points on one side and some on the other, passes through Tübingen (36·7 miles), the last trustworthy point, until it reaches Breslau one minute before the observed time, with a velocity of at least fifteen miles a minute.

The Herzogenrath earthquake of October 22, 1873, leads to somewhat similar results. In drawing the hyperbolic hodograph, some of the best observations, those used for determining the position of the epicentre, have to be rejected altogether, while others must be supposed to err by as much as two or three minutes. But a curved line, passing through the mean positions of the points, is concave throughout on its lower side, with a large curvature at the epicentre. The figure certainly differs little from the form of the hodograph corresponding to a centre at the surface, and the inner zone is a circle of not more than four kilometres radius.

Thus the best investigated earthquakes at our disposal show that the observations agree much less closely with the older theory of concentric earthquake-waves, straight rays and hyperbolic hodograph, than they do with the new theory of a velocity of propagation increasing with the depth, rays convex downwards, and a hodograph with points of inflexion.

The Determination of the Depth of the Centre.—If the law connecting the velocity with the depth were known, we should be able to calculate the forms of the corresponding rays and hodograph, and to find a relation between the depth of the centre and the form of the hodograph. In Fig. 2 we have started with the simplest assumption, and supposed the velocity to vary as the depth. As this law is an entirely arbitrary one, the figure can only give a nearer approach to the truth than the theory represented in Fig. 1. If, for instance, the modulus of elasticity were to vary as the depth, the velocity would change much more rapidly near the earth's surface than far below it; and the fact that the perceptibility of earthquakes decreases so rapidly as the depth increases, certainly indicates that a rapid change in the velocity takes place immediately below the surface. Consequently, in calculating the depth of the centre corresponding to our law, we should find too large a value. Other difficulties in determining the depth of the centre are our ignorance of the true superficial velocity, and the uncertainty as to the form of the hodograph, especially the doubtful position of its points of inflexion. But, in spite of all these difficulties, we may consider it as a rule that the depth will increase with the radius of the inner zone of the disturbed area, and that it will certainly always be smaller than this radius.

On the other hand, a minimum value of the depth may be found by means of the tangent at the point of inflexion. This tangent in Fig. 2, like the asymptote in Fig. 1, makes an angle of 45° with the horizon, because in both figures the central velocity (u_1) was taken as the time scale. While in Fig. 1 the asymptote passes through the centre, in Fig. 2 the tangent at the point of inflexion passes above it. Now, let us imagine the depth of the centre in Fig. 2 to remain the same, as well as the velocities u_1 at the centre, and u at the surface; but let the increase of velocity be no longer uniform as before, but be principally restricted to the neighbourhood of the surface. The consequence will be that the rays will differ little from straight lines at first when they leave the centre, and that the principal increase of curvature will be near the surface. The point of emergence of that ray which leaves the centre horizontally, will move to a greater and greater distance, and, as the same is the case with the point of inflexion of the hodograph, its tangent at that point will be displaced parallel to itself downwards; and when the whole change is imagined to take place in the surface itself, the hodograph will coincide with Seebach's hyperbola, and the tangent at the point of inflexion becomes an asymptote and passes through the centre.

Thus, with a hodograph adapted as well as possible to the existing observations, we find a depth of more than five, and less than ten, geographical miles for the earthquake in Central Germany, and a depth of less than three kilometres for the earthquake of Herzogenrath. Each of these earthquakes represents a special type. Type I., with a very small depth of centre and an approximate disappearance of the inner zone, is represented by the earthquake of Herzogenrath; Type II., in which both zones are pretty equally distinct, and the depth is rather considerable, by the earthquake of Central Germany. There may exist a Type III. with a very deep centre, or with small intensity and moderate depth, for which the point of inflexion of the hodograph falls outside the region when the earthquake is perceptible, and where, consequently, the hodograph is convex throughout. Amongst the earthquakes so far studied, for which the mean velocity has been calculated, those with small velocities, which generally have a merely local character, may safely be regarded as belonging to the first type.

THE TOTAL SOLAR ECLIPSE OF AUGUST 8, 1896.[1]

IT having come to my knowledge that some doubts had arisen as to the suitability of Norway as a post of observation for the total eclipse of the sun in 1896, and having had both experience in total eclipse expeditions and of travelling in Norway, I determined to make a special tour of observation both to the west coast, and also to Finmarken, Lapland, and the Russian frontier on the east coast.

In selecting stations in such an exceptional country as Norway, many points must be considered that do not apply to most places; thus it is not enough to know that A is twenty miles from B without also knowing how many fjords lie between, how many peaks three or four thousand feet in height, how many glaciers, and how far they are crevassed, if the mountains are passable, and if so what weight besides himself a man can carry up. Those people who have visited Norway, and the more so those who have travelled in the interior and north of the country, are surprised at the almost impossibility of moving at all except by the fjords and certain made roads. These generally may be said to extend as far north as Trondhjem, latitude 63° 26′; longitude 10° 30′ about. After that, on the north and north-east coast and Russian frontier, roads are the feeblest tracks generally, and the fjord communication only of a special character; the population, except at such places as Tromso, Hammerfest, Vardo, and Vadso, is very scanty, and chiefly confined to the sea coast, and in the latter case subject to consider-

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[1] Abridged from a paper read before the Royal Astronomical Society, by Col. A. Burton-Brown (*Monthly Notices*, R.A.S., vol. lv. No. 3).